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QUARTERLY PROGRESS REPORT TO THE OFFICE OF NAVAL RESEARCH
FOR THE PERIOD JUNE 1, 1989 TO AUGUST 31, 1989

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Joel Michael \
Allen Rovick
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Rush Medical College

Note: We are making this first report in letter form since this
seems to be the most rational way to describe the startup
process.

INTRODUCTION

The main focus of our work at Rush has been on the taping of
human-to-human tutoring sessions and the analysis of the
transcripts of those sessions with regard to both language and
content. The language analysis involves study of vocabulary,
syntax, semantics, and discourse for use in the understanding of
ill-formed input and the generation of responses. The analysis
of content focuses on tutoring rules, modeling rules, and the
underlying knowledge used by the tutor.

At IIT we are working on the development of the lexical
functional grammar rules and lexicon for the cardiovascular
sublanguage, on the development of a cardiovascular knowledge
base for the tutoring system, on a Prolog prototype for the
tutor we are trying to build, and on the initial plans for a
tutoring system in Lisp to support our research in text
generation.

The context of our work is an attempt to build an intelligent
version of a remarkably effective "conventional" tutoring
program, CIRCSIM, designed and implemented in Basic by Joel
Michael and Allen Rovick. CIRCSIM is intended to tutor first
year medical students in the complex negative feedback processes
used by the human body to maintain blood pressure. An important
first stage in our work has been to examine and make explicit the
knowlege base and tutoring strategies implicit in CIRCSIM and to
study the ways in which students interact with this program.
Much of this work has been done by Michael and Rovick at Rush; it
has been used by an IIT Ph.D. student Nakhoon KIm in building a
prototype version of the "intelligent" CIRCSIM-TUTOR.

We are motivated by the conviction that the best way to develop
intelligent tutoring systems is by evolution not revolution -
that the most effective ITS will evolve from the most effective
conventional systems. The insight of expert teachers is
essential - as is observation of interactions between the

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tutoring system and real students of the material. This means that it is necessary to maintain a working system at each step of the evolutionary process. Our focus is on the provision of natural language dialogue, which we feel is a key ingredient in tutoring. The use of Lexical Functional Grammar reflects our belief that it combines computational tractibility with psycholinguistic insight not available in any other current model of language.

ANALYSIS OF LIVE TUTORING SESSIONS

In May 1989 at Rush we carried an experiment in which we asked four medical students to solve a particular problem in cardiovascular physiology with the assistance of an experienced tutor (JAM or AAR). The problem was a paper and pencil exercise requiring the student to predict the qualitative changes that will occur to seven parameters describing a negative feedback system as the result of applyting a perturbation to the system. The particular negative feedback system in question is the one that stabilizes blood pressure in man. The tutor attempted to assist the student in arriving at a correct solution to the problem posed and a correct understanding of the domain in which the problem is situated. The verbal output of both student and tutor was recorded and transcribed into a text file using a standard word processing program (Word Perfect 5.0).

The session transcripts are being studied from two different points of view - we need to perform detailed analyses of both the language and the content. The analysis of language starts off with vocabulary, syntax, semantics, and discourse structures. The analysis of content begins with a search for tutoring rules and then goes on to student modeling rules. We are also studying the underlying domain knowledge used by the tutors. When we have worked out the analysis process thoroughly, we plan to record a number of sessions in which our colleagues tutor other students.

The first step in analysis is a simultaneous review of tape and transcript by one of the tutors to correct spelling and put all sentences and sentence fragments into a standard form with uniform punctuation. Then a simple program assigns a unique number to each sentence or fragment that identifies the session, the speaker (tutor or student), and the turn. This makes it possible to analyze each sentence separately and also associate it with the context that it came from. We already have programs to pull out vocabulary items and form a KWIC index. A phrase counter program pulls out possibly relevant phrases and submits them for human judgment. We are planning further software to aid in the sublanguage study. So far our attempts to extract tutoring and student modeling rules from the sessions have been entirely manual - a kind of debriefing: "What were you trying to do here?" "How did this student response adjust your ideas about where the confusion lies?" We need to systematize this process

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and devise a better method of representing the content.

LEXICAL FUNCTIONAL GRAMMAR (LFG)

Ronald Kaplan of Xerox Palo Alto Research Center has given us a
copy of the toolkit for Lexical Functional Grammar that he has
developed. Ru-Charn Chang, an IIT graduate student, and David
Levin, a member of the Philosophy Department of the University of
Wisconsin-Parkside, have been using Kaplan's system in developing
grammar rules and lexical entries for the cardiovascular
sublanguage used in Joel Michael's introductory chapter on
cardiovascular physiology. Kaplan is interested in our work
because we are one of the first groups to try to construct a
coherent syntax and lexicon describing a significant subset of
English. We hope that this part of our research will be of
interest in itself and will lead to separate publications.

The Xerox PARC software is ideal for developing grammar rules and
vocabulary for the cardiovascular sublanguge, but it responds
much too slowly for use in a tutoring system. Ru-Charn Chang has
started work on a Prolog prototype of an LFG parser. It uses a
bottom-up left corner strategy and implements some but not all of
the grammar rules from the collection that she and David Levin
have put together.

DOMAIN KNOWLEDGE BASE

A domain knowledge base is a central component of an intelligent
tutoring system and the contents of that knowledge base are as
crucial as the routines that search it, extract knowledge from
it, and reason with that knowledge. We expect to discover more
about the appropriate contents of that knowledge base and how it
is used from analysis of the tutoring sessions. We are also
attacking this problem using two other approaches - one based on
a study of the knowledge embodied in CIRCSIM, the other on an
analysis of a manuscript on cardiovascular physiology written by
Joel Michael.

Glenn Mayer is using Naomi Sager's Linguistic String Parser (LSP)
to analyze this manuscript. He has begun his sublanguage
analysis by extracting words and phrases and building a KWIC
index of the manuscript. (These have been very helpful to Chang
and Levin.) He is now adding LSP grammar rules, restrictions,
and vocabulary classification to handle sentences that either
cannot be parsed or that yield inappropriate parses. His plan is
to convert the parse trees into information formats; then to
convert the information formats into frames linked together by
ISA relationships as well as causal and spatial relationships.

It is clear that this step will require the use of a core
knowledge base developed by hand, corresponding to the basic
knowledge that Michael expects from the students who read his

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chapter or work with CIRCSIM. We have had a most convincing
demonstration of the need for this knowledge base from three of
the Korean students involved in our project. They could not read
Michael's chapter in spite of the fact that they can speak
English fluently and can read complex texts in computer science.
What was missing, we realized, was the understanding of the
western view of how the human body functions, which most
Americans acquire in high school biology courses, if not earlier.
Michael gave them two lectures of which we have careful notes.
The first describes in elementary terms the chambers of the
heart, the main arteries and veins, and the lungs. The second
describes the flow of blood through the system carrying oxygen
and waste products. With this background the students could then
read Michael's discussion of the volume and pressure mechanisms
that control blood pressure - the core material for CIRCSIM and
CIRCSIM-TUTOR.

In developing the knowledge base for the prototype tutor
described below, Nakhoon Kim translated these notes into Prolog
facts linked together in a semantic net. Yuemei Zhang has now
organized this information into a collection of frames for the
LISP system linked together by a number of different semantic
relationships. She has also developed Lisp routines for
retrieving information needed by her text generation system.

PROLOG PROTOTYPE

Nakhoon KIm has developed a Prolog prototype for CIRCSIM-TUTOR, in
partial fulfillment of the requirements for the Ph.D. in Computer
Science. His prototype contains a screen manager, an expert
system capable of solving CIRCSIM problems, a student modeler, a
control module that contains lesson planning rules and simple
tactical rules, and a simple parser for student questions. The
textual response to these questions is either produced by filling
in the blanks or totally canned (copied from the CIRCSIM
program).

The Prolog prototype is capable of carrying through a CIRCSIM
tutoring session with a student, in which the student is guided
through the process of filling out a prediction table. The
system detects errrors by comparing the student's solution with
its own, builds a simple student model based on an overlay of the
concept map, comments on errors, and answers simple questions.
The development of the prototype has given us the opportunity to
work out simple lesson planning rules and tactical rules to
support them. It has forced us to consider the student modeling
problem. Most important of all, it gives us a setting in which
to collect natural language input from students and watch their
reaction to natural language output.

It falls short of the CIRCSIM TUTOR that we plan to build over
the next two years in four important ways:

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(1) The control module now handles two levels of rules, lesson-planning rules and tactical rules. We need the capacity to do complex multi-level planning of the tutoring discourse. The tutoring rules are oversimplified in many ways. They do not teach problem solving algorithms at all; the student is forced to solve subproblems in the correct order by the program flow.

(2) The student modeler is definitely unsophisticated. It models the student's knowledge of physiology processes in a simple one dimensional fashion and does not even try to model the problem solving processes involved.

(3) The natural language umderstanding system can understand only simple questions from the student phrased in complete, perfectly grammatical sentences.

(4) The natural language generation process is rudimentary.

CIRCSIM-TUTOR ON THE XEROX LISP MACHINE

We are now beginning the development of a version of CIRCSIM-TUTOR written in Common Lisp. Chong Woo is working on a multilevel planner that will control the whole system. It will interpret rules at a number of different levels. Leemseop Shim is writing the student modeler, trying to develop a system that can accommodate both overlay and bug library kinds of information. He is using certainty factors to express the system's level of confidence in the student's knowledge of particular material. Yoon Hee Lee has completed a spelling correction program and is working on an LFG parser for ill-formed input in LISP, using many ideas from Ru-Charn Chang's Prolog parser but adding a chart to store intermediate results. A chart seems the most natural approach to handling the fragments that appear so frequently in the taped sessions and that we expect will be even more frequent when the students are using the keyboard for natural language input.

Yuemei Zhang is starting work on the design of the text generation module. As mentioned above she has been working on the problem of extracting appropriate material from the knowledge base to support text generation. She is also studying the discourse structures in the tutoring sessions to obtain ideas for discourse schemas for the text generator.

OTHER ACTIVITIES

Four of us went to the International Conference on Computer-Aided Learning (ICCAL) in Dallas in May. I gave an invited talk on the importance of natural language in intelligent tutoring systems. I also took part in a panel session on the testing of tutors in which I emphasized the importance of working closely with experts in the teaching of the domain knowledge and on trying out ideas

with real students. Joel Michael and Allen Rovick gave papers about the pathophysiology tutor and tutoring rule editor designed and implemented by IIT student M. Moidul Haque. (We had expected Haque to give one of these papers himself but he was detained in India by his wife's illness.) Nakhoon Kim presented a paper about the Prolog prototype and gave a live demonstration. All three of these papers appear in the Proceedings.

Allen Rovick came back from the workshop at Cornell full of excitement at the new ideas he had heard in discussions there; we have all been reading the papers he brought back.

Since Nakhoon Kim's thesis work is an essential foundation of the research supported by ONR, we used ONR funds to pay for his trip to Dallas and also to support him this summer. Yuemei Zhang has assumed major responsibility for the text generation research and therefore we supported her part time this summer and we are paying both tuition and stipend for her this fall.

We are most grateful for the loan of a XEROX Lisp machine to Rush. This means that we can easily demonstrate components of the Lisp system to Michael and Rovick while they are still in progress and also that students will be able to use successive versions of the system as it develops. It is also increasingly valuable as a development resource as more of us become involved in programming and in expanding the knowledge base. At the same time we are looking carefully at the possibility of moving our work to a Macintosh. We are moving from Interlisp to Common Lisp as quickly as possible to facilitate a change of hardware.

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